ESMAP
Energy Sector Management Assistance Program

SUSTAINABLE ENERGY FOR ALL

EXECUTIVE SUMMARY

BEYOND CONNECTIONS
Energy Access Redefined

CONCEPTUALIZATION REPORT

ESMAP MISSION

The Energy Sector Management Assistance Program (ESMAP) is a global knowledge and technical assistance program administered by the World Bank. It provides analytical and advisory services to low- and middle-income countries to increase their know-how and institutional capacity to achieve environmentally sustainable energy solutions for poverty reduction and economic growth. ESMAP is funded by Australia, Austria, Denmark, Finland, France, Germany, Iceland, Lithuania, the Netherlands, Norway, Sweden, and the United Kingdom, as well as the World Bank.

Beyond Connections: Energy Access Redefined (ESMAP Technical Report 008/15) full report and associated materials are forthcoming.

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Energy Sector Management Assistance Program | The World Bank

FOREWORD

Access to energy is vital to economic, social and human development. To be meaningful for households, productive enterprises and community facilities, the energy supply supporting that access must have a number of attributes: it must be adequate in quantity, available when needed, of good quality, reliable, convenient, affordable, legal, healthy, and safe.

Access to this sort of energy changes lives. It can reduce human effort, enhance comfort and enable telecommunications, education and better heathcare, while also extending useful waking hours. It can reduce the time spent on the drudgery of fuel gathering and benefit women and girls in particular, and curb the health-damaging impacts from smoky cookstoves.

Access to a reliable and quality energy supply can also boost productivity and economic activity which can in turn create opportunities for jobs and incomes. It can facilitate the delivery of education, health services, e-governance, and improve public safety on the streets. This is why universal access to energy by 2030 is one of the three goals of the Sustainable Energy for All (SE4All) initiative.

This new report from the SE4All Knowledge Hub—*Beyond Connections: Energy Access Redefined*—conceptualizes a new multi-tier framework for defining and measuring access to energy. Binary metrics such as whether a household has an electricity connection, and whether a household cooks with non-solid fuels don't help us understand the phenomenon of expanding energy access and how it impacts socioeconomic development. This report heralds a new definition and metric of energy access that is broader—it covers energy for households, productive engagements and community facilities, and focuses in on the quality of energy being accessed.

How does that alter our conception of the challenge of universal energy access? Beyond Connections shows that the access challenge is not just limited to the 1.1 billion households that lack electricity connections. It is as much a challenge for the hundreds of millions of households around the world with poor and unreliable electricity supplies. The goal of universal access must also cover energy for household cooking and heating and for productive engagements and community facilities.

While our understanding of the universal energy access challenge has expanded, so has our understanding of what's needed to meet this challenge. There are many ways to expand energy access—from more extensive electricity grids to off-grid solutions like solar lanterns, solar home systems and mini-grids, and improved cookstoves and clean fuels. Equally, improvements in supply through generation, transmission and distribution strengthening, and demand management through energy efficiency measures all contribute to energy access.

The multi-tier framework underlying *Beyond Connections* will prove to be a tool for measuring and goal-setting, investment prioritization, and tracking progress. It will help us capture the multiple modes of delivering energy access from grid to off-grid and to the range of cooking methods and fuels. It will also help reflect the contributions of various programs, agencies, and national governments toward achieving the SE4All goals.

In a follow-up report, we will learn methodologies for applying this framework to projects, programs and country contexts. Experience from pilots in a number of countries will help demonstrate the methodologies in action. Eventually, the rollout of a global multi-tier survey will give us much finer detail on the quality of energy access across all countries.

Beyond Connections changes the paradigm of measuring energy access. We commend this report as another vital tool in our quest for sustainable energy for all.

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EXECUTIVE SUMMARY

Access to energy is a key enabler of socioeconomic development. Energy is needed for multifarious applications across households, productive uses, and community infrastructure. "Universal access to modern energy by 2030" has been proposed as one of the three key pillars of the Sustainable Energy for All (SE4All) program, an initiative co-chaired by the United Nations (UN) Secretary General and the World Bank President. Achieving this goal would require a wide range of interventions by various agencies. Tracking progress toward this goal, therefore, would require an approach that captures the contribution of all of these efforts, as well as encompass quantity and quality aspects of improvements. SE4All's Global Tracking Framework (GTF) 2013 report introduced multi-tier frameworks for measuring energy access. It identified tasks for improved measurement of energy access over the medium term, including further development of the multi-tier frameworks. This report is a culmination of the multi-agency effort on developing multi-tier frameworks to fulfill the mandate suggested by the GTF 2013 report.

CONCEPTUAL BACKGROUND

The concept of access to energy does not lend itself to an easy definition. In the past, access to energy usually was considered synonymous with household access to electricity. It has been defined variously as a household electricity connection, an electric pole in the village, and an electric bulb in the house. However, these definitions do not take into account the quantity and quality of electricity provided. There are many instances where connected households receive electricity at low voltage, for limited hours, during odd hours of the day (or night), and with poor reliability. Further, this approach does not address the questions of affordability of energy and legality of connection. A definition of energy access based on household electricity connection also ignores energy for cooking and heating needs, as well as for productive engagements and community facilities.

To develop a comprehensive definition and measurement approach for energy access, the key concepts underlying this phenomenon must be examined. Some of these key concepts are:

1. **Access to energy can mean many things.** The distinction between *access to energy supply, access to energy services,* and *actual use of energy* must be clearly reflected in the definition of energy access. The definition should also capture the phenomenon of access achieved through stacking of multiple energy solutions.
2. **Socioeconomic development is the primary objective of expanding energy access.** The services that energy provides are critical ingredients for socioeconomic development, including the achievement of Sustainable Development Goals (SDGs).
3. **Accessed to energy is needed at multiple locales.** Socioeconomic development requires increased use of energy services across households, productive engagements, and

community facilities. At the household level, access to energy encompasses electricity as well as cooking and heating solutions. Access to energy for productive engagements increases income, productivity, and employment, while delivering higher quality and lower priced goods. Access to energy for community infrastructure (such as schools, health facilities, and government offices) can lead to substantial improvements in service delivery, human capital, and governance.

4. **Access pertains to *usability of supply* rather than *actual use of energy*.** The usability of energy is the potential to use the available energy supply when required for the applications that a user needs or wants. The energy provided should have all the necessary attributes for use in these applications. The actual use of energy may be constrained by exogenous factors despite an adequate access to energy supplies. Further, after adequate access to an energy supply is achieved, the actual use of energy generally increases gradually over time. To get a complete picture of energy access, both usability of energy supply and actual use of energy should be measured.

5. **Attributes of the energy supply affect the usability of energy for desired services.** The attributes of energy include adequacy (capacity), availability, reliability, affordability, quality, legality, health impact, safety, and convenience, among others. The definition and measurement of access to energy should focus not only on the number of users benefitting from improved energy access, but also the nature and degree of that improvement across various attributes.

6. **Improvement in energy access refers to a continuum of improvements in attributes of energy supply**. Improvement in energy access is not a single-step transition from lack of access to availability of access. Instead, it is a continuum of increasing levels of energy attributes. This forms the basis of a multi-tier conceptualization of energy access to reflect the continuum versus a binary conceptualization.

7. **For standalone energy solutions, the collective attributes of the energy supply and conversion device are taken into account.** Standalone devices such as solar lanterns and cookstoves deliver a complete energy service (lighting or cooking) rather than just energy supply. In such a case, the collective attributes of the energy supply and the conversion device should be taken into account when examining energy access.

8. **All interventions in the energy sector can contribute to improved access by moving users to higher levels of attributes.** Such interventions not only include new household electricity connections and delivery of clean cookstoves, but other projects such as power generation, transmission, gas pipelines, liquefied petroleum gas (LPG) bottling, mini-grid systems, solar home systems, biogas projects, fuel-wood plantations, and briquette manufacture, among others. In addition, soft aspects such as policy formulation, credit mechanisms, market structuring, regulatory reforms, institutional capacity development, consumer services enhancement, loss-reduction measures, efficiency improvement, and other aspects may also contribute to enhanced access to energy.

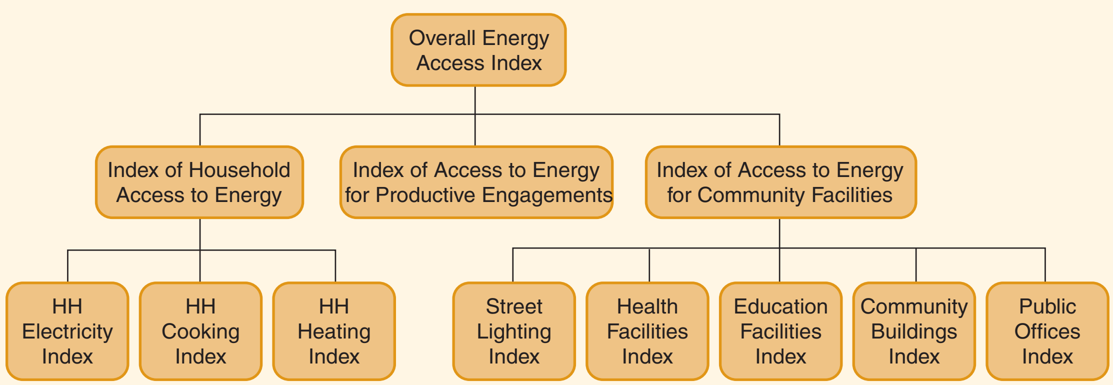
OVERARCHING FRAMEWORK

The broad areas of energy use—(i) households, (ii) productive engagements, and (iii) community facilities—are termed as the *locales of energy access.*

For the household locale, the proposed multi-tier framework examines (i) access to electricity, (ii) access to energy for cooking solutions, and (iii) access to energy for space-heating solutions as three separate sub-locales. Separate multi-tier frameworks are defined for each of these components. Separate indices of energy access are calculated for each of the components, defined as the average tier rating across households in the given area adjusted to a scale of 100. The overall index of household access to energy may be calculated as the average of the three sub-locale indices (Figure ES.1). This overall index involves an apples-and-oranges aggregation across sub-locales and is less meaningful than the individual indices.

For the productive engagements locale, the proposed multi-tier framework examines the energy supply vis-à-vis critical energy applications. Measuring energy needs for productive uses is a complex challenge. There are multiple types of productive enterprises, encompassing different scales of operation, varying degrees of mechanization, a multitude of energy applications, and a variety of energy supplies. Further, it is not possible to set norms of energy needs for different enterprises or applications to measure energy access deficits. Also, lack of adequate energy access may not be the only constraint to functioning and expansion of the productive enterprise, which may be constrained by raw materials, capital, land, skilled manpower, markets, transportation, government licenses, or other inputs. Specifying minimum energy needs of different types of enterprises would be a very

FIGURE ES.1
Hierarchy of Energy Access Indices



Note | HH = household

cumbersome approach. Also, it is important to capture energy needs of small and micro enterprises and productive engagements in the informal sector, which are often not reflected in enterprise surveys that tend to focus on large enterprises.

To address these challenges, an approach based on surveys of individuals for their key productive engagements and energy needs is proposed. Under this approach, energy access for productive engagements is aggregated across individuals, thus eliminating the need for reflecting the relative scale of operations of different enterprises. Although this approach may suffer from less-accurate reporting about energy needs of individuals working in larger enterprises, it would be better suited for most countries where an overwhelmingly high proportion of people work in informal or micro- and small-scale enterprises. An index of access to energy for productive uses for any given geographical area can be calculated as the average tier level across all individual respondents in that area, adjusted to a scale of 100. In addition, sub-indices can also be calculated for various productive activities (e.g., small shops, artisans, or agriculture) by taking the average of tier levels across respondents engaged in those activities.

For the community facilities locale, five sub-locales need to be considered—(i) health facilities, (ii) schools, (iii) street lighting, (iv) government buildings, and (v) public buildings. Access to energy for each sub-locale can be determined based on surveys of either the users of the facility or the providers of the facility. The former requires a survey of households, whereas the latter requires a survey of the relevant community institutions. Whereas the former can only yield subjective and limited information, more detailed information can be obtained from the latter. Multi-tier frameworks are defined for each of the sub-locales, and separate indices are calculated based on the average tier rating for each sub-locale, adjusted to a scale of 100. The overall index of access to energy for community facilities is calculated as the average of indices across the five sub-locales.

For any geographical area, an overarching index of access to energy can be calculated as the average of the indices across the three locales—households, productive uses, and community facilities.

Household Locale

Household Access to Electricity

Binary metrics for tracking access to household electricity fail to capture the multifaceted nature of access to electricity. Binary measurement of electricity access is usually based on whether a household has a grid connection. However, poor electricity supply from the grid may limit its usefulness. Use of electricity may also be constrained by its affordability. Illegal connections may cause significant financial losses to the utility, while also increasing the risk of accidents. Further, electricity access through off-grid standalone and mini-grid solutions needs to be tracked in addition to grid connections, according suitable weights based on the amount and quality of electricity delivered.

Access to electricity is measured based on technology-neutral multi-tiered standards where successive thresholds for supply attributes allow increased use of electricity appliances. The key attributes relevant for household electricity are: (i) capacity, (ii) duration (including daily supply and evening supply), (iii) reliability, (iv) quality, (v) affordability, (vi) legality, and (vii) health and safety. The multi-tier standards for household access to electricity supply are summarized in Table ES.1.

A separate multi-tier framework can be defined for access to electricity services. A gradually improving electricity supply enables increased and improved access to electricity services. Therefore, a second matrix measuring access to household electricity services mirrors the supply matrix, based on the type of appliances used in the household (Table ES.2). It is possible for a household to obtain different tier ratings across access to electricity supply and access to electricity services—reflecting either availability of appliances despite poor supply or inability to afford appliances (or high electricity consumption despite adequate supply).

A third multi-tier framework is defined for electricity consumption. This framework is closely aligned with tiers of electricity services. The thresholds for annual consumption level at each tier are based on the indicative hours of use for select appliances. A consumption-based metric cannot accurately reflect the diversity of appliances actually used by the household, nor appropriately account for energy efficiency. Also, tiers of consumption are distinct from tiers of energy services, which are different still from tiers of energy supply (Table ES.3).

Access to lighting using stand-alone devices requires separate attention. Many of these devices do not meet the Tier 1 threshold, but may yet contribute significantly to improved access. This is discussed separately in the next section.

Data for populating the multi-tier frameworks can be obtained through demand-side and supply-side measurements. Demand-side measurement involves collecting data from electricity users through household energy surveys and the use of sensor-based instrumentation. Supply-side measurement can use utility or project and program data. However, in the developing country context, utility data may suffer from several deficiencies.

Results can be compiled and analyzed to produce an energy access diagnostic. Data can be dissected to analyze different attributes of electricity supply for a disaggregate analysis. A single-number index representing the level of access to household electricity supply may be compiled based on the multi-tier matrix. Respective indices of access to electricity supply, services, or consumption can be defined as the average tier rating across all households in the given area. The indices and disaggregated data may be compared across countries or any geographic area (subnational, regional, and worldwide). Similarly, the indices and data may be compared over time to track progress.

TABLE ES.1

Multi-tier Matrix for Access to Household Electricity Supply

ATTRIBUTES			TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
	1. Capacity	Power[1]		Very Low Power Min 3 W	Low Power Min 50 W	Medium Power Min 200 W	High Power Min 800 W	Very High Power Min 2 kW
		AND Daily Capacity		Min 12 Wh	Min 200 Wh	Min 1.0 kWh	Min 3.4 kWh	Min 8.2 kWh
		OR Services		Lighting of 1,000 lmhrs per day and phone charging	Electrical lighting, air circulation, television, and phone charging are possible			
	2. Duration	Hours per day		Min 4 hrs	Min 4 hrs	Min 8 hrs	Min 16 hrs	Min 23 hrs
		Hours per evening		Min 1 hrs	Min 2 hrs	Min 3 hrs	Min 4 hrs	Min 4 hrs
	3. Reliability						Max 14 disruptions per week	Max 3 disruptions per week of total duration < 2 hours
	4. Quality						Voltage problems do not affect the use of desired appliances	
	5. Affordability					Cost of a standard consumption package of 365 kWh per annum is less than 5% of household income		
	6. Legality						Bill is paid to the utility, prepaid card seller, or authorized representative	
	7. Health and Safety						Absence of past accidents and perception of high risk in the future	

[1] *The minimum power capacity ratings in watts are indicative, particularly for Tier 1 and Tier 2, as the efficiency of end-user appliances is critical to determining the real level of capacity, and thus the type of electricity services that can be performed.*

TABLE ES.2

Multi-tier Matrix for Access to Household Electricity Services

	TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Tier criteria	Not applicable	Task lighting Phone charging	General lighting Television Fan (if needed)	Tier 2 AND Any medium-power appliances	Tier 3 AND Any high-power appliances	Tier 4 AND Any very high-power appliances

TABLE ES.3

Multi-tier Matrix for Electricity Consumption

	TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
Annual consumption levels, in kilowatt-hours (kWh)	<4.5	≥4.5	≥73	≥365	≥1,250	≥3,000
Daily consumption levels, in watt-hours (Wh)	<12	≥12	≥200	≥1,000	≥3,425	≥8,219

Household Access to Lighting and Phone Charging

Modern lighting and phone charging are important first steps toward improved household electricity access. Electricity offers 10 times more affordable lighting than fuel-based lighting (on the basis of cost per lumen-hours) but still fails to reach over a billion people. For households that are just starting to climb the energy ladder, lighting and mobile phone charging are critical first applications. Access to modern lighting extends useful hours of the day, and also improves public health and safety. It reduces the economic burden of costly (on the basis of per lumen-hour) fuel-based lighting, while also delivering superior quality of light. Access to mobile charging improves social connectivity, enhances financial inclusion and economic activity, facilitates emergency assistance, and supports broader development by providing a platform for mobile governance.

Fractional measurement between Tiers 0 and 1 is used to reflect less than Tier 1 access. To reflect the benefit of pico-solar and other small-scale devices that contribute improved lighting but may not meet Tier 1 standards, fractional measurement is used between Tier 0 and Tier 1.

Lighting is an excludable good, while phone charging is a common good. Small amounts of light is usually difficult to share physically among multiple members of a household. As a result, access to light using entry-level lighting solutions is often an individual rather than household service. Mobile telephony, on the other hand, is treated as a common good because the benefits of phone charging access are often shared within the household.

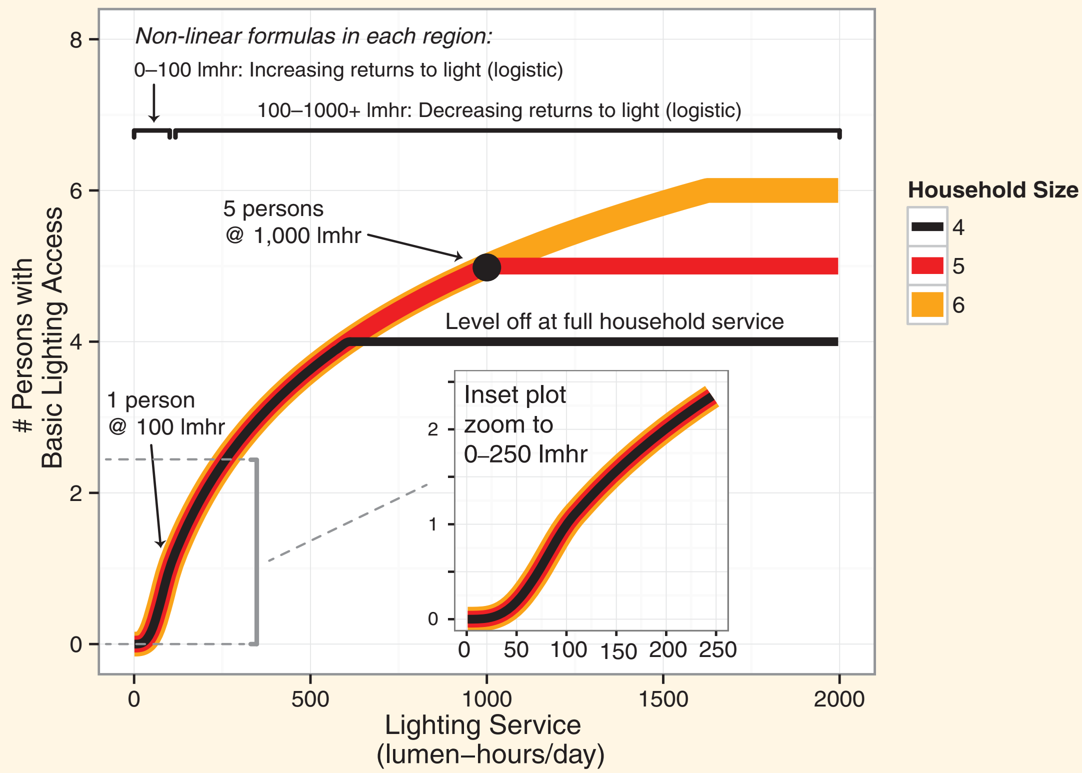
The three core benchmark levels of lighting service are at 0, 100, and 1,000 lumen-hours per day. Data collated by Lighting Global reveals that over 90 percent of people across Africa and India are satisfied with brightness levels around 25 lumens, and use of about 4 hours each evening. Based on the observation that low-level lighting is an individual service, a benchmark is placed at 100 lumen-hours for meeting the needs of one person. Use of a shared light source simultaneously by multiple persons can reduce its utility because it is difficult to spatially distribute light across more than one person. Thus, there are declining access returns on additional light as more people are served, up to a full household of 5 being served by 1,000 lumen-hours. This represents another benchmark level for lighting. Two different mathematical functions are used to link the benchmarks, as shown in Figure ES.2.

Energy for phone charging is defined in terms of watt-hours of electricity. Full credit for phone charging access is given if available supply can charge approximately one phone every day, whereas partial (two-thirds) credit is given if one phone can be charged every three days. In the event the phone recharging service is only available in the neighborhood, one-third credit is given.

Relative weightage of lighting and phone charging is specified. A weighted average tier score is calculated across lighting (70 percent weight) and phone charging (30 percent weight). This tier score is used as the tier rating of households that do not have access to any higher level electricity supply solutions.

FIGURE ES.2

Number of Persons with Basic Lighting Access from a Single Source of Lighting



For devices from 0 to 100 lmhr/day	For devices from 100 to 1,000+ lmhr/day	Total number of persons served in the household
A logistic function	*A logarithmic function*	*A summation function*
$P_l = d\left(1 - \frac{1}{1 + (\frac{L}{e})^f}\right)$ where: P_l = number of persons served with lighting service by the device L = quantity of available light (lmhr/day) $d = 2$ $e = 100$ $f = 3.3$	$P_l = 0 < h_{base} \times \log 10\left(\frac{L}{a} + b\right) - c < h$ where: P_l = number of persons served with lighting service by the device L = quantity of available light (lmhr/day) $a = 95$ $b = 0.732$ $c = 0.0515$ $h_{base} = 5$ h = household size	Sum for all the light sources in a household: $P_{tot} = \max\left(\sum_{i}^{All} P_{l,i}, h\right)$ $T_l = \frac{P_{tot}}{h}$ where: P_{tot} = number of persons served with lighting service in total h = household size T_l = effective tier for lighting

Household Access to Cooking Solutions

The multi-tier framework for measurement of access to energy for cooking is based on seven attributes: health (based on household air pollution), **convenience** (based on fuel collection time and stove preparation time), **safety, affordability** (including expenditure on cookstove and fuel), **efficiency, quality, and availability.** This report refers to a cooking solution as the combination of a cookstove and a type of cooking fuel taken together. A cooking system includes all cooking solutions being used, as well as the cooking location and ventilation.

Although distinct, **the multi-tier framework for household access to energy for cooking has been defined in a manner that is consistent with the International Workshop Agreement on Cookstoves (IWA) tiers for measuring cookstove performance.** To avoid any confusion with the IWA "tiers" for cookstoves, the proposed multi-tier framework uses the term "levels" for improving echelons of attributes of cooking access. The levels reflect simultaneous increase in attributes related to indoor air quality (for health), convenience, safety, affordability, cookstove efficiency, and fuel quality and availability. An index of household access to cooking solutions for any given geographical area can be calculated as the average of levels across all households in that area, adjusted to a scale of 100 (Table ES.4).

Data for access to energy for cooking may be collected through demand-side sources (household energy surveys) or supply-side sources (program, project, and manufacturer data). However, data on some attributes and parameters are only feasible from demand-side measurement, such as ventilation, quality of fuel used, convenience, availability, and affordability. Other parameters, such as indoor air quality and efficiency, can be measured better through supply-side data based on testing or through estimation based on mathematical modeling.

Household Access to Space-Heating Solutions

In many households, cooking solutions also serve to meet heating needs. Energy for space heating, however, can be availed though a range of solutions, including electric heating, fuel-based centralized district heating, fuel-based standalone heating, and direct solar heating.

Household access to heating (where needed) is measured using a separate multi-tier framework, and a separate index of access to energy for space heating is calculated (Table ES.5).

TABLE ES.4

Multi-level Matrix for Access to Cooking Solutions

	Attribute	Indicator	LEVEL 0	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5
ATTRIBUTES	1. Indoor Air Quality	PM2.5 (μg/m3)		[To be specified by a competent agency such as WHO based on health risks]	[To be specified by a competent agency such as WHO based on health risks]	[To be specified by a competent agency such as WHO based on health risks]	< 35 (WHO, IT-1)	< 10 (WHO guideline)
		CO (mg/m3)					< 7 (WHO guideline)	< 7 (WHO guideline)
	2. Cookstove Efficiency (Not to be applied if cooking solution is also used for space heating)			Primary solution meets Tier 1 efficiency requirements [to be specified by a competent agency consistent with local cooking conditions]	Primary solution meets Tier 2 efficiency requirements [to be specified by a competent agency consistent with local cooking conditions]	Primary solution meets Tier 3 efficiency requirements [to be specified by a competent agency consistent with local cooking conditions]	Primary solution meets Tier 4 efficiency requirements [to be specified by a competent agency consistent with local cooking conditions]	
	3. Convenience	Stove preparation time (min/meal)			< 7	< 3	< 1.5	< 0.5
		Fuel acquisition and preparation time (hrs/wk)			< 15	< 10	< 5	< 2
	4. Safety of Primary	IWA safety tiers			Primary solution meets (provisional) ISO Tier 2	Primary solution meets (provisional) ISO Tier 3	Primary solution meets (provisional) ISO Tier 4	
		OR Past accidents (Burns and un-intended fires)					No accidents over the past year that required professional medical attention	
	5. Affordability						Levelized cost of cooking solution (including cookstove and fuel) < 5% of household income	
	6. Quality of Primary Fuel: variations in heat rate due to fuel quality that affects ease of cooking						No major effect	
	7. Availability of Primary Fuel						Primary fuel is readily available for at least 80% of the year	Primary fuel is readily available throughout the year

Note: CO = carbon monoxide; ISO = International Organization for Standardization; IWA = International Workshop Agreement on Cookstoves; PM = particulate matter.

TABLE ES.5

Access to Space Heating Multi-tier Matrix

ATTRIBUTES		LEVEL 0	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5
1. Capacity			Personal space around individuals is heated	At least one room has heating		All rooms in the household have heating	
2. Duration					At least half the time when needed (> 50% of the time)	Most hours when needed (> 75% of the time)	Almost all hours when needed (> 95% of the time)
3. Quality					Comfortable temperature at least 50% of the time	Comfortable temperature at least 75% of the time	Comfortable temperature all the time
4. Convenience (Fuel collection time)				Max 7 hr/wk	Max 3 hr/wk	Max 1.5 hr/wk	Max 0.5 hr/wk
5. Affordability					Max 2 times grid tariff		Max grid tariff
6. Reliability					Max 3 disruptions per day	Max 7 disruptions per week	Max 3 disruptions per week of total duration < 2 hours
7. Indoor Air Quality (Health)	PM2.5 (μg/m3)		[To be specified by a competent agency such as WHO based on health risks]	[To be specified by a competent agency such as WHO based on health risks]	[To be specified by a competent agency such as WHO based on health risks]	< 35 (WHO, IT-1)	< 10 (WHO Guideline)
	CO (mg/m3)					< 7 (WHO Guideline)	< 7 (WHO Guideline)
8. Safety						No accidents (burns or unintended fires) over the past year that required professional medical attention	

Note: BLEENS = biogas, LPG, ethanol, electricity, natural gas and solar; CO = carbon monoxide; kWh = kilowatt-hours; LPG = liquid petroleum gas; Max = maximum; Min = minimum; PM = particulate matter; W = watts; Wh = watt-hours; WHO = World Health Organization.

Access to Energy for Productive Engagements

Productive uses of energy are defined as those that increase income or productivity, referred to as value-adding activities. The wide diversity of productive activities and enterprises makes it difficult to devise a common metric for energy access. There are hundreds of different types of productive uses, with varying scales of operations and varying degrees of mechanization. Each productive use may involve different energy applications and may use energy from different sources. Energy applications can be broadly classified as lighting, information and communication, motive power, space heating, product heating, and water heating. Measurement is also constrained by survey limitations, including the need to address the informal sector.

The proposed multi-tier framework is based on the energy access experienced by individuals in their productive engagements. In the course of a household energy survey, the earning members are identified first. Next, the relevant energy applications are identified based on significant impact of these energy applications on productivity, sales, cost, or quality. Thereafter, the primary energy source for each application is identified and evaluated for the eight key attributes of energy supply.

The multi-tier framework (Table ES.6) is built on eight attributes that determine the usefulness of the supply for each application needed for the productive activity. Access to energy is first assessed for each application separately. The lowest tier among all applications determines the energy access rating for the productive use as a whole. The multi-tier framework captures the multiple attributes that influence access to energy for productive uses, in order to inform policy and investment.

The index of access to energy for productive enterprises is calculated as the average tier rating across the entire sample of individuals surveyed, adjusted to a scale of 100. Additional indices for specific engagements can be calculated by filtering the survey data for respondents engaged in the particular productive use, such as agriculture, small shops, and artisans.

Access to Energy for Community Facilities

Energy for community facilities is fundamental for socioeconomic development. It drives improvements in human capital through education and health services. Street lighting can improve mobility and security and encourage economic and social activity. Energy access in health facilities is a critical enabler of access to health services. Access to energy in education facilities increases the time students spend at school and improves children's and teachers' experience. Access to energy in government buildings enables e-governance, as well as necessary communications. Energy services in community buildings (such as prayer and celebration halls) allow the use of these institutions during evening hours as well.

The wide diversity of community facilities makes it difficult to devise a common measurement approach. Measurement of street lighting has to encompass coverage as well as brightness, whereas that for community institutions needs to reflect a wide variety of energy services and energy sources. The proposed framework captures separately street lighting and energy for community institutions (Tables ES.7 and 8, respectively).

Two different approaches for collecting information are considered: direct assessment through survey of community institutions and indirect assessment through survey of users. Both approaches entail measurement of various attributes of energy supply—capacity, duration, reliability, quality, affordability, legality, convenience, and health and safety—though the survey of users can only

TABLE ES.6

Multi-tier Matrix for Measuring Access to Productive Uses of Energy

				TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
ATTRIBUTES	1. Capacity	Electricity	Power		Min 3 W	Min 50 W	Min 200 W	Min 800 W	Min 2 kW
			Daily supply capacity		Min 12 Wh	Min 200 Wh	Min 1.0 kWh	Min 3.4 kWh	Min 8.2 kWh
			Typical source		Solar lanterns	Solar home systems	Generator or mini-grid	Generator or grid	Grid
		Non-electric					Available non-electric energy partially meets requirements	Available non-electric energy largely meets requirements	Available non-electric energy fully meets all requirements
		Both					No relevant application is absent solely due to energy supply constraints		
	2. Duration of daily supply	Electricity			Min 2 hrs	Min 4 hrs	Min 50% of working hours	Most of working hours (Min 75%)	Almost all of working hours (Min 95%)
		Non-electric					Available non-electric energy partially meets requirements	Available non-electric energy largely meets all requirements	Available non-electric energy fully meets all requirements
		Both					Longer working hours are not prevented solely by lack of adequate energy (capacity or duration)		
	3. Reliability							No reliability issues that have severe impact	No reliability issues or little impact
	4. Quality							No quality issues that have severe impact	No quality issues or little impact
	5. Affordability							Variable cost of energy is less than two times the grid tariff	Variable cost of energy is less than grid tariff
	6. Legality							Energy bill is paid to the utility/pre-paid card seller/authorized representative/legal market operator	
	7. Convenience							Time and effort in securing and preparing energy does not cause severe impact	No convenience issues or little impact
	8. Health (Indoor air quality from use of fuels)	PM2.5 (µg/m3)			[To be specified by competent agency such as WHO]	[To be specified by competent agency such as WHO]	[To be specified by competent agency such as WHO]	< 35 (WHO, IT-1)	< 10 (WHO Guideline)
		CO (mg/m3)						<7 (WHO Guideline)	<7 (WHO Guideline)
		OR Use of Fuels (BLEENS)				Use of non-BLEENS solutions (if any) for heating in the open or with smoke extraction		Use of BLEENS or equivalent solutions only (if any)	
	9. Safety							Energy supply solutions have not caused any accidents over the past year that required professional medical assistance	Energy supply solutions have not caused any accidents over the past year

Note: BLEENS = biogas, LPG, ethanol, electricity, natural gas and solar; CO-carbon monoxide; kW = kilowatts; kWh = kilowatt-hours; LPG = liquid petroleum gas; Max = maximum; Min = minimum; PM = particulate matter; W = watts; Wh = watt-hours; WHO = World Health Organization.

TABLE ES.7

Multi-tier Matrix for Access to Street Lighting

	STREET LIGHTING	TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
ATTRIBUTES	Capacity		At least 1 functional street lamp in the neighborhood*	At least 25% of the neighbor-hood is covered by functional street lamps	At least 50% of the neighbor-hood is covered by functional street lamps	At least 75% of the neighbor-hood is covered by functional street lamps	At least 95% of the neighbor-hood is covered by functional street lamps
	Duration		Street lighting functions for at least 2 hrs/day	Street lighting functions for at least 4 hrs/day	Street lighting functions for at least 50% of night hrs/day	Street lighting functions for at least 75% of night hrs/day	Street lighting functions for at least 95% of night hrs/day
	Reliability					No reliability issues perceived by users	
	Quality					No brightness issues perceived by users	
	Health and Safety					No perceived risk of electrocu-tion due to poor installation or maintenance	

** Neighborhood is defined as area within a distance of 0.5 km from the household.*

deliver limited information about select attributes. An important aspect of energy supply is the financial sustainability, which refers to the ability of the community institution to pay for utility bills, fuel, spares, maintenance, and batteries.

An index representing the level of access to energy at each type of community facility may be compiled based on the multi-tier framework.

STRENGTHS AND SHORTFALLS OF PROPOSED MULTI-TIER METHODOLOGY

Strengths of the Proposed Methodology

The proposed multi-tier framework enables a comprehensive assessment of energy access, spanning across various locales and attributes. Apart from a comprehensive treatment of energy access measurement, the approach offers the following advantages:

Gap analysis and diagnostic review. The aggregate and disaggregate analysis under the proposed approach enable an energy access diagnostic review that provides insights into possible interventions that would enable enhanced access. An energy access diagnostic review report can be prepared using the survey information, which can then be used for planning, investment prioritization, and program design.

TABLE ES.8

Multi-tier Matrix for Measuring Access in Community Institutions (for Survey of Institutions)

ATTRIBUTES			TIER 0	TIER 1	TIER 2	TIER 3	TIER 4	TIER 5
1. Capacity	Electricity	Power		Min 3 W	Min 50 W	Min 200 W	Min 800 W (Min 2 kilowatt-hours (kW) for institutions)	Min 2 kW (Min 10kW for institutions)
		Daily supply capacity		Min 12 Wh	Min 200 Wh	Min 1.0 kWh	Min 3.4 kWh	Min 8.2 kWh
		Typical source		Solar lanterns	Solar home systems	Generator or mini-grid	Generator or grid	Grid
	Nonelectric					Available nonelectric energy partially meets requirements	Available nonelectric energy largely meets requirements	Available nonelectric energy fully meets all requirements
	Both					No relevant application is absent solely due to energy supply constraints		
2. Duration of Daily Supply	Electricity			Min 2 hrs	Min 4 hrs	Min 50% of working hours	Most of working hours (Min 75% of working hours)	Almost all of working hours (Min 95% of working hours)
	Nonelectric					Available nonelectric energy partially meets requirements	Available nonelectric energy largely meets all requirements	Available nonelectric energy fully meets all requirements
	Both					Longer working hours are not prevented solely by lack of adequate energy (capacity or duration)		
3. Reliability							No reliability issues that have severe impact	No reliability issues or little impact
4. Quality							No quality issues that have severe impact	No quality issues or little impact
5. Affordability							Variable cost of energy is less than 2 times the grid tariff	Variable cost of energy is less than grid tariff
6. Legality							Energy bill is paid to the utility, prepaid card seller, authorized representative, or legal market operator	
7. Convenience							Time and effort in securing and preparing energy does not cause major inconvenience	No convenience issues or little impact
8. Health and Safety	Health: Use of fuels (BLEENS)				Use of non-BLEENS solutions (if any) for heating in the open or with smoke extraction		Use of BLEENS or equivalent solutions only (if any)	
	Safety						Energy supply solutions have not caused any accidents over the past year that required professional medical assistance.	Energy supply solutions have not caused any accidents over the last one year

Note: BLEENS = biogas, LPG, ethanol, electricity, natural gas and solar; kW = kilowatts; kWh = kilowatt-hours; LPG = liquid petroleum gas; Max = maximum; Min = minimum; W = watts; Wh = watt-hours.

Foundation for establishing energy access targets and multifarious analytics. The multi-tier treatment of energy access can form the foundation for establishing realistic targets for achieving universal access. It also enables extensive analytics that can provide further insights into energy access-related aspects. Socioeconomic benefits of energy access can be assessed based on the measured/assumed energy access index. For example, Tier 1 access may lead to certain socioeconomic benefits, whereas Tier 3 access may deliver very different benefits.

Information on gender aspects. The multi-tier approach provides information on several gender-related aspects, including:

- Availability of various electrical appliances that may deliver greater use-benefit to either gender
- Role of members of different genders in cooking and cooking fuel collection
- Various aspects of cooking, including time spent and health impacts of indoor air pollution
- Availability of street lighting in the neighborhood area
- Availability and use of energy by women for productive enterprises
- Availability of energy at health clinics for child deliveries

Comparison across geographies and over time. The multi-tier approach provides a robust tool for measuring access across various locales of energy use, and comparing them across geographies and over time. The indices of energy access also allow aggregation across geographies, using simple weighted averages.

Shortfalls of the Proposed Methodology

The shortfalls of the proposed methodology are as follows:

Critique of multi-tier approach. The proposed methodology is complex and involves tier thresholds that many practitioners may consider subjective. Also, different attributes are independent of each other, and cannot be assumed to improve simultaneously across tiers. However, there are several examples of use of simultaneously increasing attribute standards that deliver better performance of the system.

Critique of data-collection approach. The complex multi-tier framework requires extensive collection of data, which may not always be affordable. On the other hand, the proposed methodology does not cover some aspects that may be of interest to some practitioners. These aspects can be added into the standard survey instrument as additional modules. To facilitate data collection through various survey opportunities, three different levels of the multi-tier framework are proposed.

Critique of mathematical formulation of indices of energy access. The methodology underlying the indices of access to energy converts ordinal values of different tiers into cardinal values of energy access. This conversion may not be mathematically robust. An analysis of the shortfalls of the underlying methodology and options for addressing them are in the main report.

Simplified Frameworks for Global Assessment

To address the complexity of the multi-tier framework, three different levels of the framework can be envisaged: (i) comprehensive framework, (ii) simplified framework, and (iii) minimalistic framework (Table ES.9).

TABLE ES.9

Levels of the Proposed Multi-Tier Framework

	COMPREHENSIVE FRAMEWORK	SIMPLIFIED FRAMEWORK	MINIMALISTIC FRAMEWORK
Key Purpose	Detailed survey questionnaire for country-level assessment that can be used for diagnostic review	Reduced number of questions that may be used for global assessment of energy access under SE4All	Minimum questions that may be incorporated in existing household surveys such as the DHS and LSMS
Household Characteristics	Covered in detail, including, inter alia, education, social, occupational, basic income, and expenditure characteristics	Covered in a simplified manner without assessment of income and expenditure	Not covered separately (already covered by existing surveys)
Household Electricity Access	Comprehensive assessment based on all attributes: capacity, duration, reliability, quality, affordability, legality, convenience, safety and health	Simplified assessment based on reduced set of attributes: capacity, duration, reliability, quality	Minimalist assessment based on select attributes: capacity, duration
Household Lighting Access	Comprehensive assessment based on lumen-hours of lighting and phone-charging capability, including use behavior	Simplified assessment based on type of lighting device and phone-charging capability	Minimalist assessment based on use of electrical lighting and phone charging capability
Household Cooking	Comprehensive assessment based on all attributes and information about ventilation, cooking area, conformity to standards, and maintenance	Simplified assessment based on primary and secondary cooking solutions as well as ventilation, convenience and affordability	Minimalist assessment based on type of primary and secondary cooking solutions
Household Heating	Comprehensive assessment based on all attributes	Simplified assessment based on capacity, duration, and convenience of primary heating solution	Not included
Productive Uses	Detailed assessment based on all relevant activities and sources of energy	Simplified assessment based on electricity access	Not included
Community Uses	Detailed assessment based on survey of institutions	Simplified assessment based on household interviews	Not included

EXPANDING ENERGY ACCESS THROUGH UPSTREAM PROJECTS

Upstream energy projects such as electricity generation and transmission can also be considered as energy access projects, provided that they move households to higher tiers of access by improving deficient attributes in the existing electricity system.

Increased availability of electricity from new generation capacity, rehabilitated capacity, or power imports can improve the duration of supply in areas that may have previously experienced load shedding. Peaking stations (or peaking imports) improve supply during evening hours, which is usually when households find electricity most useful. Further, the supply voltage is also likely to improve as the grid as a whole receives adequate electricity generation. Reliability of the system improves with frequency stabilization resulting from better matching of supply with demand. Reliability also improves with lesser plant breakdowns upon rehabilitation. All of these infrastructure projects enable consumers in the target area benefitting from the additional generation to move from access Tiers 1, 2, 3, and 4 to Tiers 3, 4, and 5.

Similarly, transmission, sub-transmission, and distribution-strengthening projects improve reliability and reduce losses. More importantly, these projects create the necessary infrastructure for connecting new households and supporting higher demand for electricity from already connected ones. They enable unconnected households (typically Tiers 0, 1, and 2) to get connected (typically Tiers 3, 4, and 5), while also enhancing the tier rating of connected households through improved availability, reliability, and affordability of electricity.

CONCLUSION AND NEXT STEPS

Use of multi-tier frameworks for measuring energy access is currently constrained by limited availability of data—mainly from existing household surveys. The Global Tracking Framework (GTF) 2013 Report proposed to implement these multi-tier frameworks over the medium term by alleviating data constraints. It proposed to develop standardized survey instruments, conduct periodic household energy surveys, analyze the data to assess various aspects of energy access, and make such data available in the public domain. Apart from multi-tier tracking, such surveys could potentially serve the data needs of multiple stakeholders, including governments, regulators, utilities, project developers, civil society organizations, developmental agencies, financial institutions, appliance manufacturers, international programs, and academia. The detailed frameworks and survey instrument presented in this report pave the way for wider use of multi-tier measurement by strengthening the availability of data, as envisaged in the GTF 2013.

A four-pronged approach is suggested for strengthening the availability of data for monitoring progress on expansion of energy access:

1. **Incorporation of the minimalistic framework into existing household survey questionnaires.** Existing household surveys such as the Demographic and Health Survey (DHS) and the Living Standards Measurement Survey (LSMS) cover a wide range

of information pertaining to multiple sectors, and offer limited space for energy-related questions. The minimalistic framework has been specifically formulated to leverage the limited space for additional questions in existing household surveys such as the DHS and LSMS. This minimalistic approach needs to be implemented by expanding existing household surveys through a dialogue with the International Household Survey Network.

2. **Global survey to establish baseline for SE4All.** To establish the multi-tier baseline for the purposes of SE4All, a global survey would be required, covering at least the top 30 to 40 energy access-deficit countries, and representing about 80 to 90 percent of the binary energy access-deficit population. This global household survey would be centrally administered through a suitable survey agency that has outreach in the selected countries. Such a global survey is likely to be constrained in terms of length of the questionnaire and the sample size in each country (in view of the costs involved). The simplified version of multi-tier framework and survey instrument would be used for this survey. The survey is being planned for 2016, and necessary funding is being arranged for the same. Similar surveys can be organized periodically (every 2 to 3 years) for tracking progress under SE4All.

3. **Detailed country-level surveys.** At present, various international and national agencies conduct household energy surveys for their own project, program, or planning needs. This results in significant expense of time, effort, and resources for collecting overlapping data, even as data from different surveys are not comparable due to lack of standardization of questionnaires, sampling strategies, and coverage. SE4All offers a unique opportunity to integrate all such survey efforts into a standardized household energy survey (customized to specific country needs) conducted every 2 to 3 years at the country level that could serve the needs of the multi-tier framework and the requirements of most stakeholders. Such surveys would use the comprehensive framework, encompassing all attributes across all locales, and can also provide an energy access diagnostic review for the country.

4. **Adoption of multi-tier measurement approach by programs and projects.** The multi-tier approach can be adopted by various agencies for programs and projects for supply-side and demand-side measurement. Many agencies were involved in the development of the multi-tier frameworks. As mentioned earlier, supply-side measurement can be based on the performance characteristics of solutions supplied, whereas demand-side measurement can be done through household surveys using the proposed survey instruments.

A combination of the four approaches just described can be used for regular tracking of progress on expansion of energy access. Periodic global and country-level surveys would form the backbone of such a tracking mechanism, and data and information from programs and projects could be used to track incremental progress in between two global surveys.

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